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ABSTRACT *(MAXIMUM 200 WORDS)*

The all STOVL force provides economy of scale by combining the logistical requirements of three different aircraft into one. Instead of three aircraft for the price of one, however, the Marine Corps is getting one aircraft for the price of three. The all STOVL force is a tactical and economical mistake. The Marine Corps is a niche force that requires niche aircraft to prosecute the mission. Trying to make one STOVL aircraft fill the roles of three different communities will result in a degraded product for the Marines on the ground. The Marine Corps needs the F-35B, but it also needs a diverse air arm capable of efficiently fighting the full spectrum of future conflicts.

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MASTER OF MILITARY STUDIES

Hovering at a Precipice:
Does Obsession with an all STOVL Force Unnecessarily Endanger the Future of Marine Corps Tactical Fixed-wing Aviation?

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

Lieutenant Commander Alexander P. Solomon V
United States Navy

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Mentor and Oral Defense Committee Member: Dr. Douglas E. Streusand
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Oral Defense Committee Member: Dr. Paul D. Gelpi
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Executive Summary

Title: Hovering at a Precipice: Does obsession with an all STOVL force unnecessarily endanger the future of Marine Corps tactical fixed-wing aviation?

Author: Lieutenant Commander Alexander P. Solomon, United States Navy

Thesis: The Marine Corps desire to transition its tactical air assets to an all STOVL force inexorably ties the fate of Marine tactical fixed-wing aviation to the rise and fall of the maligned F-35 program.

Discussion: The Marine Air-Ground Task Force (MAGTF) is a synergistic force that requires organic air assets to provide support to and enhance the performance of the ground combat element. A key enabler in the doctrine of Operational Maneuver from the Sea (OMFTS), sea-based STOVL attack aircraft provide the MAGTF with close air support and escort vulnerable rotary wing assets. The Marines require a new STOVL aircraft to replace the aging AV-8B "Harrier II" and have chosen the F-35B "Lightning II". In order to afford the expensive F-35B through an economy of scale, the Corps plans to merge all of its tactical fixed wing communities into this one aircraft. Without alternatives to mitigate the effects of continued changes in the cost and delivery date of the F-35B, Marine Corps leaders have tied the fate of their air force to the largest and most ambitious aviation program ever attempted.

Conclusion: The all STOVL force provides economy of scale by combining the logistical requirements of three different aircraft into one. Instead of three aircraft for the price of one, however, the Marine Corps is getting one aircraft for the price of three. The all STOVL force is a tactical and economical mistake. The Marine Corps is a niche force that requires niche aircraft to prosecute the mission. Trying to make one STOVL aircraft fill the roles of three different communities will result in a degraded product for the Marines on the ground. The Marine Corps needs the F-35B, but it also needs a diverse air arm capable of efficiently fighting the full spectrum of future conflicts.

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THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Preface

As a Naval Aviator and strike-fighter pilot, I have served with Marines my entire career. I have been stationed aboard a Marine Corps Air Station and have had the privilege to fly combat missions alongside and in support of Marines. If the tone of this paper leaves you feeling that I am hypercritical of the JSF, the Marines, or STOVL aircraft, I have missed the mark. My desire is to logically expose the tactical detriment of a homogenized force. I believe that the gradual disappearance of tactical aircraft that specialize in specific missions is transforming us into an air force that, while still very capable, is not fostering expertise in specific fields.

It was without hesitation that I chose to attend the Marine Corps Command and Staff College to fulfill my requirement for Joint Professional Military Education. The motivation to research and study of this topic stems from my heartfelt desire to better understand the subject and communicate my perceptions. I would like to thank Dr. Douglas E. Streusand and my classmates for their support and tolerance of my incessant questioning of our guest lecturers on this topic. Most of all, I would like to thank Colonel Raymond Damm, USMC for his enthusiastic nurturing of my thesis and my professional development. For the last five years, I have benefitted from Colonel Damm's mentorship and patience in his efforts to teach me *how* to think, not *what* to think.

Introduction

The United States Marine Corps has embarked upon a comprehensive overhaul of its aviation force scheduled to culminate in fifteen years with the replacement of every airframe currently in service.[1] To reduce the compounding costs associated with operating multiple varieties of fixed and rotary wing aircraft, the Marine Corps will transition from thirteen to six type/model/series of manned aircraft in the next ten years.[2,3] In doing so, Marine Corps aviation will attain a goal forty years in the making: the fielding of an entire light attack force capable of short take-off and vertical landing (STOVL).[4] To make an all STOVL force an attainable and affordable goal, the Corps intends to transition all four of its tactical fixed-wing platforms[5] into one new airframe. That airframe will be the STOVL variant of the Joint Strike Fighter (JSF): the F-35B Lightning II. As of early 2010, the F-35B is four years behind schedule and the per unit acquisition cost has exceeded one hundred twenty million dollars – more than triple the amount envisioned by the Joint Initial Requirements Document (JIRD) for the JSF.[6,7] The "B" model of the F-35 is one of three variants in concurrent production for the USAF, USMC, and USN. Unarguably the most complex variant of the three to design, test, and produce, yet required to reach initial operational capability (IOC) first, the F-35B is a monumental aviation program. In proclaiming the F-35B a critical capability for the future of Marine Corps aviation[8] and pursuing no viable alternatives to its full-scale procurement, Marine Corps leadership has accepted an untenable amount of risk. The United States Marine Corps must, at least privately, explore options to the wholesale procurement of the F-35B or stand-by to weather the consternation of another complex STOVL program (like the MV-22 Osprey) entering flight test and the inevitable set-backs that will cause pundits to question the viability of Marine Corps fixed-wing tactical

aviation. The Marine Corps needs the F-35B, but it cannot afford (doctrinally or fiscally) to have nothing but the F-35B.

This paper will examine the history of designing and employing fixed-wing STOVL aircraft for operations from ships and austere forward bases. How the unique capabilities of STOVL aircraft enabled a revolution in amphibious warfare doctrine is examined as a key to understanding how the F-35B will bring to fruition the concept of Operational Maneuver from the Sea. Contrasted herein are the facts and fallacies surrounding the current tactical operation of STOVL aircraft and the Marine Corps' plans for the future. As an argument for the continued existence of Marine Corps tactical fixed-wing aviation, tactical flexibility and sea basing are reviewed as keystone capabilities of the Marine Air-Ground Task Force. This paper offers alternatives to the all STOVL force, presenting them as logical choices to save money, diversify the force, and provide a more robust capability to support Marines on the ground. Economizing the force by homogenization is exposed as detrimental to the mission of the United States Marine Corps.

Enabling Concepts and Myths of STOVL Attack Aircraft

> The airplane won't amount to a damn, until they get a machine that will act like a hummingbird – go straight up, go forward, go backward, come straight down and alight like a hummingbird. It isn't easy … Somebody is going to do it.
> - Thomas Edison (1847-1931)

STOVL aircraft pay a penalty for their ability to land vertically. A conventional take-off and landing (CTOL) aircraft of the same construction and dimensions as a STOVL aircraft will be able to fly farther and deliver more ordnance to the target. The extra space and weight required by the STOVL-specific propulsion and mechanical controls equates to a reduction in the lifting capability of the aircraft ("useful load" in aviation speak). The space and weight occupied by lift fans, nozzles, and ducting for vertical flight operations translates directly into more room

for bombs and fuel in a CTOL aircraft. STOVL aircraft can operate from conventional long runways and make a longer take-off roll in order to increase their useful load. In practice, this is how land-based Harriers in Iraq and Afghanistan operate in order to maximize the amount of fuel and ordnance they bring to the fight.[9] The inefficiency of operating STOVL aircraft as CTOL aircraft is that there is no way to remove the weight and volume penalties associated with the STOVL specific mechanical equipment and design features built into the aircraft. Whether you need it or not, it is always there. Often it is taking-up valuable space that the pilot would rather fill with fuel.

The F-35 program offers a remarkable "apples-to-apples" comparison of the exact penalties STOVL aircraft pay for their unique capability when compared to CTOL aircraft. Historically there was room for debate, but with the F-35 program (and the demand for parts commonality) there has never been a more impartial comparison. The F-35B and F-35C have overall similar dimensions and are powered by the exact same engine. The F-35B, however, has 75% the combat radius of the F-35C and carries less than half as much ordnance for short take-off.[10,11] The time-honored defense for the deficiencies of STOVL aircraft is their ability to operate closer to the front lines and out of austere locations. Doing so compensates for their reduced range and payload with faster response times to calls for fire. The ability to re-arm and return to the fight faster than CTOL aircraft allows for a higher sortie generation rate.

A product of 1960s tactical requirements, NATO Basic Military Requirement-3 (NBMR-3) was the initial concept of operations that called for a supersonic vertical/short take-off and landing (V/STOL) aircraft to support NATO forces. NBMR-3 operated under a Cold War scenario in Europe where the USSR would deny NATO the use of traditional bases with long runways in the opening days of a conflict.[12] Based on NBMR-3, the United Kingdom

developed the Harrier from concept into a mature weapons system and successfully deployed Harrier units to Europe in simulated combat exercises on several occasions in the 1970s.[13] Forward basing of STOVL aircraft in dispersed sites proved tactically feasible but logistically challenging. The same principles that made dispersed sites difficult for the enemy to target made them difficult to resupply with fuel and ordnance.[14]

After thirty years of STOVL operations, the logistical challenges remain. In Operation Desert Storm (1991) and Operation Iraqi Freedom (2003), there has been no demand for sustained STOVL operations from forward bases or austere locations. When coalition planners deployed Harriers closer to the forward line of troops, it was to suit the aircraft's operational construct. Battlefield conditions did not necessitate dispersed operations, but the Harrier's limited range and payload required forward basing so that higher sortie rates could compensate for inferior performance. In Desert Storm, Harriers operated out of conventional bases alongside CTOL aircraft. There were examples of forward arming and refueling points (FARPs) established in soccer stadiums along the Saudi border, but only for contingency operations in the early hours of the offensive.[15] For OIF, only one Harrier squadron was operating ashore, and that shore base was a conventional field with long runways. The remaining five Harrier squadrons operated from amphibious ships in the northern Arabian Gulf.[16] Fuel tanker availability constricted the use of FARPs because it was difficult to keep fuel moving forward with the rapidly advancing coalition forces. On the one occasion that USMC Harriers were able to operate on the side of a highway outside Baghdad, the FARP was rocketed minutes after the Harriers departed. After that incident, STOVL forward operations were limited to captured enemy airfields.[17] Not only is forward basing a logistical quagmire, as the price of these aircraft continues to climb and the number scheduled for purchase continues to descend, they will

become national assets that are closely guarded. The United States does not usually base national assets within range of the enemy's indirect fires. In 2005, a rocket attack destroyed one British Harrier and damaged another while they sat on the ramp in Kandahar, Afghanistan.[18] It seems dubious to expect $120M+ fifth-generation STOVL fighters like the F-35B to operate out of forward bases or austere locations. They may retain the capability to do so, but at the expense of range and useful load.

The doctrinal concept of Operational Maneuver from the Sea (OMFTS) recognizes the challenges faced by Marine logisticians as they phase combat power ashore. General Krulak envisioned that "with sea-based logistics, fire support, medical facilities, and command and control assets, [the] force maximizes its protection by limiting its footprint—and hence its vulnerability—ashore."[19] For the low-intensity littoral conflicts of the future, OMFTS will be the touchstone doctrine. The Marine Corps needs a new STOVL attack aircraft to replace the aging Harrier, but not because it will operate from forward bases or in austere locations. The Corps needs a new STOVL fighter because of how Marines deploy within an Amphibious Ready Group (ARG). Marines deploying from the deck of an Amphibious Assault Ship (LHA or LHD) and operating independently of a larger Carrier Strike Group (CSG) need fixed wing tactical aircraft organic to the ARG that will support their movement ashore. The idea of a fifth generation STOVL stealth fighter based near the front that will "bring unprecedented responsiveness to the fight"[20] is a red herring that continues to propagate from the highest levels of the Marine Corps.

General Krulak and OMFTS

In the Spring of 1999, only months before his retirement, General Charles C. Krulak (31st Commandant of the Marine Corps) wrote an article for *Joint Forces Quarterly* entitled

"Operational Maneuver from the Sea." The doctrine of OMFTS was several years old by this time, but in his article General Krulak laid out the concepts as they applied to the future missions of the Marine Corps and the specific equipment the Corps would need to carry out these missions.

The 1990s were seminal years for the USMC, both in the Corps' approach to internal mission analysis and their procurement strategies for selecting weapons systems to accomplish the mission. OMFTS developed out of multiple Department of the Navy white papers concerning the mission of a post Cold War naval service. These papers analyzed specifically the future of war in the littorals and how the Navy would transform itself to face a future irregular threat in a near-shore fight. At a time when the future of the MV-22 program was in constant flux, General Krulak's article identified the Osprey as one of three enabling technologies required to achieve OMFTS.[21] The other two components of the OMFTS triad described by General Krulak were the programs that would develop into the Expeditionary Fighting Vehicle (EFV) and the F-35B. The Commandant's article is also noteworthy because it is the first time that the STOVL variant of the JSF appears as part of the OMFTS triad. In initial versions of the doctrine, the third enabling technology cited was the LCAC (Landing Craft Air Cushion).[22]

The similarities of these three "triad" programs are remarkable when analyzed side-by-side. The USMC is the primary customer and requirements author for each program. Each system has faced cost and schedule over-runs that have threatened to cancel the program. The most historic commonality among these programs is that they represent the first time the Marine Corps (on a large scale) has taken an acquisition program all the way from concept to IOC.

Historically, the Corps has utilized mature systems already in production and adapted those systems to their specific requirements. The procurement of the AV-8A Harrier is a perfect

example. In 1971 the USMC reached IOC with its first squadron of AV-8As.[23] The AV-8A was purchased "off the shelf" from Hawker-Siddley in Britain. Hawker-Siddley built every AV-8A for the USMC at their factory in the United Kingdom. The Marine Corps was able to procure a mature system without paying a pound for research and development, thus allowing for a relatively low risk entry into a revolutionary technology. The Marines had, of course, used this procurement strategy before – usually buying aircraft designed for the Navy or Air Force. This had often meant adapting an airframe to do a mission (like close air support or forward observation) that it was not initially designed to do. With the procurement of the AV-8, the Marine Corps broke with the other services in airframe commonality, and lost the shared benefits that come with other services (or partner nations) funding a hardware or software upgrade that is applicable across the entire fleet. Up to this point, the Marines had always flown the same planes or variants of planes flown by the Navy or Air Force and enjoyed the sometimes intangible benefits of commonality.

In 1965, the Army, Navy, and Air Force purchased six "Kestrel" jump jets (the predecessor to the Harrier) from Hawker Siddley, but the tri-service tests were for research purposes only.[24] The USAF studied the Harrier as a competitor in the A-X competition, but in the end selected to proceed with the design that would mature into the A-10 Thunderbolt II.[25] The USAF recognized that the limited range and payload of the early STOVL aircraft as limitations that would be detrimental to their mission. Only the USMC saw a niche for the Harrier and aggressively lobbied to fill it.[26]

With the Fulda Gap scenario removed and the reduced likelihood of fighting even a peer competitor, the niche mission of STOVL aircraft had shrunk considerably by the early 1990s. Operation Maneuver from the Sea is part of a larger effort by the Department of the Navy to

carve-out a slice of the post Cold War defense budget. Beginning with OMFTS, the Marine Corps changed the way they defined their mission. Penned prior to September 11th, in an era when irregular warfare and asymmetric conflict were again thought to be archaic concepts, OMFTS has survived to be a clairvoyant vision of the military challenges the United States would face in the coming decades.

STOVL from the Sea

There are currently five nations actively operating STOVL aircraft from ships: India, Italy, Spain, the United Kingdom, and the United States. For all nations except the United States, the STOVL aircraft carriers represent the capital ships of their navies. All five countries operate a version of the AV-8 Harrier as their fixed-wing light attack platform for power projection from the sea. Only the United States operates a mix of larger nuclear carriers with smaller L-class amphibious ships that are capable of launching and recovering fixed and rotary wing aircraft.

Italy and the United Kingdom are lead partners in the F-35 program.[27] For them, the F-35B is the only option to replace their Harriers for operations aboard ship. For the same reason as the European partners, procurement of the F-35B for the Marine Corps is a mandatory and unmitigated risk. The Marine Corps has a relatively deep roster (albeit an aging one) of fixed and rotary wing aircraft from which to cover gaps in land-based airpower, but when it comes to airpower for the ARG, the Harrier is the only game in town.

An ARG complemented with an L-class Amphibious Assault Ship (LHA or LHD) carrying six to ten F-35Bs will be a much more formidable force than those equipped with Harriers. The F-35B will bring an enhanced air-to-air capability over the AV-8B and its stealth qualities will allow for an expanded set of targets available to the commander. Although limited

by the number of aircraft they will embark with an entire Marine Expeditionary Unit (MEU) aboard, the expanded capability of the F-35B will allow L-class ships to operate in roles that may have previously called for a CSG and its embarked carrier air wing.

A recently published study by nine members of the Naval Postgraduate School (NPS) faculty (sponsored by the Secretary of Defense's Office of Net Assessment) looks at the force structure for the Navy of the future through the lens of "A Cooperative Strategy for 21st Century Seapower".[28] The NPS study advocates a Navy less dependent on the CVN (Nimitz/Ford Class of super carrier) as the sole progenitor of power projection and prefers a fleet capable of spreading capabilities across as many as eighteen smaller carriers (CVLs) that would carry twenty F-35Bs each.[29] Devoid of berthing spaces for Marines and the compartments for their amphibious equipment, these ships would be smaller and cheaper to build than the current L-class ships.[30] The study concedes the importance of maintaining Carrier Strike Groups for larger operations involving near-peer threats and supporting sustained major combat operations ashore, but emphasizes that these operations are not the percentage threat.

> Shifting from China (or any other peer competitor) to theater security and small wars, high performance fighter-attack aircraft are probably over-designed. An F-35B should be more than adequate because it should be able to safely perform reconnaissance and deliver strikes in almost any irregular warfare environment. These small wars and constabulary events (1) tend to be in several unpredictable places concurrently, (2) often are long lasting, and (3) often lack suitable airfields ashore for conventional combat aircraft. The United States needs seabased air in smaller packages that can be tailored to the size and duration of the problem.[31]

Small wars and constabulary events have historically been the Marine Corps bread and butter. The Banana Wars of the early twentieth century not only provided the experience and expertise espoused in the *Small Wars Manual*, the conflicts shaped the innovation of Marine aviation in a way only real combat can.[32] The lessons learned in the Caribbean and Central

America became the foundation of close air support principles pioneered by the Marines in the western Pacific during World War II and perfected in Korea a few years later.

The Corps has been making a concerted effort to refocus on their core competencies while serving as a second land army in Iraq and Afghanistan. The culmination of those efforts has been the release of a new "Service Campaign Plan"[33] that outlines the way the Marines will march back to the sea after Afghanistan. With procurement of the F-35B imminent and a concerted effort being made by the Commandant to get the Corps back in touch with their Naval heritage, the time seems ripe for the service to take for action the concept laid-out by the NPS study. The new class of LHAs that are currently under construction lack a well deck, making them look very much like a model for the CV(L) concept proposed in the NPS study.[34] While an amphibious ship without a well deck has been cause for much concern within the Marine Corps, it provides an opportunity for the Corps to exploit a new operational construct and fuse it with the future of Marine aviation.

The Gradual Transition to a Homogenous Force

In the early 1990s, the Marine Corps transitioned four different models of fixed wing attack aircraft into just two models: the F/A-18 Hornet and the AV-8 Harrier.[35] When these two communities begin their transition to the F-35B in 2012 and the EA-6B is retired, the Corps will begin to realize its goal of not only an all STOVL force, but also a fixed-wing attack force flying a single model of aircraft. The benefits of this consolidation are almost self-evident: an economy of scale that eliminates the overhead requirements (training squadrons, spare parts, maintenance depots, etc.) associated with operating multiple types of aircraft. The dangers of a homogenous air force are less obvious and deserve review.

The most obvious operational risk is a maintenance anomaly that grounds the entire fleet of aircraft until the cause of a mishap or engineering failure ascertained by investigators and engineers correct the discrepancy or mitigate its effects. A common occurrence in the Harrier community, these "red stripe" events would be crippling to a homogenous force. A noteworthy example is the grounding from 1999-2000 of the Harrier fleet due to multiple incidents involving the Pegasus engine.[36]

A less tangible operational risk assumed by a homogenized force involves the incorporation of multiple missions into one platform. The F/A-18 Hornet, lauded as the world's first true fighter-attack multi-mission aircraft, is a perfect example of the dangers associated with mission overload. Most any Hornet pilot will tell you that he or she is a "jack of all trades, master of none." With literally dozens of different weapons to employ, tactics to learn, and threats to study, the modern strike-fighter pilot is task saturated long before getting airborne. The F-35 promises to reduce the pilot's workload through improved sensor fusion and advanced information display technologies, but training and maintaining proficiency in multiple mission areas will continue to be a challenge.

Operators of advanced aircraft are not the only ones negatively affected by trying to master too many missions. Modern strike-fighter aircraft are a compromise: they are not air supremacy fighters and they lack the payload of a dedicated ground attack platform. Aircraft exist at the opposite ends of the spectrum to operate in dedicated roles and allow for the compromises made by multi-role aircraft. In the case of the U.S. Air Force, the F-22 Raptor is the world's preeminent air supremacy fighter. With local air superiority attained, the Air Force is able to bring-in the A-10 Thunderbolt II, an aircraft dedicated to providing close air support. The Marine Corps' homogenous fleet of F-35Bs will be a multi-role force without another

aircraft to complement its revolutionary capabilities or supplement the mission sets gapped by its limitations. For tactical strike and close air support missions where a low observable STOVL aircraft is not required, the Marine Corps will have no alternative but to continue to operate its expensive F-35Bs.

Why the Marine Corps needs their own Fixed-wing Attack Aircraft

All Marines are riflemen, and everything in the Marine Corps exists to support the rifleman in combat with the nation's enemies. Naval aviators in the Marine Corps attend the same flight school and wear the same Wings of Gold as their Navy counterparts, but they differ in a more fundamental way than uniforms and haircuts. Before reporting to flight school, Marines attend The Basic School (TBS) in Quantico, Virginia where they learn the fundamentals of ground combat and leading Marines in battle. This training forges an early relationship and makes clear a Marine aviator's priorities early in his or her career.

The Marine Air-Ground Task Force (MAGTF) relies on rotary and fixed-wing aviation assets to provide transport and close air support (CAS). Aviation fires are crucial to OMFTS and the principles of maneuver warfare as practice by the lightly armored Marines. Marine aviators operate as Forward Air Controllers (FACs) and provide or call-in the necessary heavy ordnance that can only come from a fixed-wing asset.

The MAGTF is a self-sufficient and self-sustaining force (not for *extended* operations ashore) that develops synergy from integrated training and employment. Before deploying, the MAGTF trains as a team to build the professional and interpersonal relationships that make it a more efficient and deadly fighting force. Taking dedicated Marine aircraft out of the MAGTF or replacing them with non-organic assets reduces the strength of the force back to merely the sum of its parts. Without Marine air, there is no MAGTF. Therefore, the notion that future joint

operations will supplant the need for Marines to have organic and dedicated air assets is indefensible.

A Loss of Flexibility within the Department of the Navy

The Marine Corps currently fields thirteen operational F/A-18 and seven AV-8 squadrons.[37] Of the eight F/A-18 squadrons that fly the single seat variant (A+ and C), three Marine Hornet squadrons are currently integrated into Navy carrier air wings (CVWs).[38] While some of the missions (such as defense of the CSG) are not intuitive to a normally MAGTF focused USMC F-18 squadron, having Marines in a carrier air wing is a multi-faceted benefit to the Navy. The driving factor behind "tac-air integration" is that the Navy does not have enough F-18s to fill all of its carrier air wings. As the Marines transition to the F-35B and the Navy begins to fill the carriers with F-35Cs, there will no longer be Marine tactical aircraft on Navy aircraft carriers.

The Marines have never deployed an F/A-18D squadron aboard an aircraft carrier. The aircraft is capable of carrier operations, but Navy planners generally cite its reduced internal fuel capacity as the reason for not integrating the two-seat Hornet into a CVW. These two-seat Hornet squadrons are the Marine Corps' platform of choice for the forward air controller airborne (FAC(A)) mission. The "D" variant of the Hornet can also be equipped for reconnaissance missions by replacing the 20mm cannon with a camera package, a mission historically in high demand by strategic and operational level commanders.

Proponents of STOVL aviation suggest that the F-35B could easily integrate into the deck cycle of an embarked CVW. The concept is not without historic precedent. From June 1976 to April 1977, VMA-231 embarked aboard USS Franklin D. Roosevelt (CV-42) with fourteen AV-8A Harriers for the ship's last deployment.[39] Although generally regarded as a

successful deployment of naval presence in the Mediterranean Sea, VMA-231's integration into the carrier air wing would be the first and last for a VSTOL squadron in the history of the United States Navy. Poorly documented from a statistical perspective, the hybrid air wing's deployment saw only low tempo operations and did not sufficiently test the concept.

Beyond the operational challenges faced by integrating STOVL operations within the fixed-wing cycle of a carrier air wing, there are mechanical limitations as well. Damage to the flight decks of L-class ships from the exhaust of the MV-22 "Osprey" is already a concern for the Navy.[40] After the Osprey returned from its maiden deployment aboard an amphibious aircraft carrier, the Navy had issues with the excessive amount of heat generated by its vertically oriented jet exhaust and its tendency to buckle the steel fight deck. Potential solutions for the MV-22 include fabricating seawater-cooled blast pads for the decks of L-class ships. There has been no actual testing to determine how F-35B exhaust will affect flight decks, but the current assumption is that they would benefit from the same solution contrived for the Osprey. Whatever the outcome, it is unlikely that the Navy will modify CVNs to accommodate the F-35B. The argument is purely conjectural at this point, since the Navy has openly stated that STOVL operations reduce the efficiency of, and have no future of concurrent operations with, an embarked carrier air wing.[41] STOVL F-35s purchased by the USMC will be limited to operating aboard L-class amphibious ships and from land bases.

Risks Associated with the F-35 Program

> While the [JSF] program must move forward, we continue to believe that the program's concurrent development and production of the aircraft is extremely risky. By committing to procure large quantities of the aircraft before testing is complete and manufacturing processes are mature, DOD has significantly increased the risk of further compromising its return on investment—as well as delaying the delivery of critical capabilities to the warfighter.[42]
>
> – U.S. Government Accountability Office, May 2009

> I would say my view is we cannot afford, as a nation, not to have this airplane.[43]
>
> - Defense Secretary Robert Gates during a media availability at the Lockheed-Martin Factory, Fort Worth, Texas, August 2009

At three hundred billion dollars, the F-35 program is the most expensive acquisition project ever funded by the U.S. Department of Defense.[44] With three variants of the F-35 in concurrent production, it will be difficult to assign a per-unit cost for each aircraft. Lockheed Martin is producing the most complex variant, the F-35B, first. As the first airframe in full-scale production, the F-35B will experience the greatest fluctuation in price if quantities later in the production run are changed. The Air Force, for example, initially planned to buy enough F-35As to replace all of its A-10s, F-16s and F-15Es. With a recently announced decision to extend the life of those legacy strike platforms, the USAF clearly signaled that they would be reducing the number of F-35s required to modernize their strike-fighter fleet. The USAF buy of 1,763 F-35As represents more than two thirds of the planned domestic production run.[45] Recent estimates of Air Force requirements for the F-35A speculate that they will likely require between eight and twelve hundred aircraft. At best, this would drive the per-unit cost over $200 million.

"Concurrency" is the buzzword for what was supposed to be a monumental cost saving manufacturing procedure. All three variants of the F-35 come off the same assembly line at the

Lockheed Martin plant in Fort Worth, Texas. Commonalities in the design and manufacturing process theoretically provide efficiencies in cost and production time. In an ideal engineering and production environment, concurrent production is without a doubt a cost saving practice. The problem faced by Lockheed Martin is that the customers declared the IOC dates for all three variants before the first production aircraft ever left the ground. The IOC dates set by the services have remained steady for several years. What has continued to slide is the operational test and evaluation dates for the different variants. IOC has become somewhat of a publicity stunt; the F-35B will reach "IOC" while it is still in operational test – a phase of production where the Department of the Navy has historically made significant changes to the airframe. In this case, concurrency may turnout to be a cost multiplier.

While multiple watchdog organizations, like the Government Accountability Office (GAO), continue to warn, "The contractor has not yet demonstrated mature manufacturing processes, or an ability to produce at currently planned rates,"[46] the Office of the Secretary of Defense remains wedded to the program. There is growing concern that the F-35 program, if allowed to continue on its present track, will violate the Nunn-McCurdy law.

> The Nunn-McCurdy law requires that Congress be notified if a program faces cost growth greater than 15 percent over the current baseline estimate. It also dictates that the project be terminated if the price climbs higher than 25 percent—a "critical" breach—unless the defense secretary certifies the program is essential to national security, that no lesser-cost alternative is available, and that cost controls are in place.[47]

The F-35 program has in fact egregiously violated Nunn-McCurdy. Whether the politics of the defense industry will allow this monumental failure to be admitted publically is yet to be seen. The longer it takes the DOD to bring this "critical breach" before Congress, the more damaging it will be.

The cancellation of the entire F-35 program is unlikely. As the program continues to struggle, however, the customers of the STOVL variant remain those with the most to lose. The defense secretary has staked his career on its success, the program is certainly essential to national security, and new cost controls are in place. What the DOD has not demonstrated is that there is no lesser-cost alternative.

The U.S. Air Force and the U.S. Navy have viable alternatives in place to await the maturation of the F-35. The Block 60 F-16E/F and the Block II F/A-18E/F are still in production and their designs incorporate modern technology that makes them "4.5 Generation" strike-fighters capable of bridging the gap between legacy aircraft and the "fifth generation" F-22 and F-35. Making them even more attractive, the aircraft currently in production represent mature technology available at affordable and fixed costs. Extending multi-year procurements of the 4.5-generation aircraft will in fact drive-down their per-unit cost and get newer technology out to the fleet faster than waiting for the perpetually delayed F-35 program.

The Imminent Danger for the Marine Corps

Marine Corps aviation is in an unnecessarily precarious position. As the price of the F-35 continues to climb, budgetary restrictions will force the Corps to make cuts in other programs or purchase fewer STOVL stealth fighters. Without argument, the F-35B is crucial to the future of Marine Corps tactical fixed-wing aviation. Without the F-35B, Operational Maneuver from the Sea is a hollow shell of a concept. Marine Corps leadership is making an existential gamble on an untested and unproven exotic weapons system. In order to guarantee that future amphibious assaults have organic fixed-wing

assets in direct support, the Marine Corps must at least acknowledge a second course of action that involves a more diversified air arm.

Risk Mitigation Strategies

Concurrent production places the entire program at risk. To ensure that the best product gets to the fleet on the first try, Lockheed-Martin should finish production of the test aircraft for each variant and transition to dedicated production of the F-35B. During the committed F-35B production run, the test aircraft for the other variants can focus on a legitimate operational test and evaluation phase to ensure that undiscovered flaws or deficiencies do not have compounding effects on the production run.

The Department of Defense should reduce the number of F-35Bs procured for the Marine Corps and buy only the number of aircraft required to fill Marine air wings dedicated to deploying with amphibious assets. This will cause the per unit cost to rise even more, but the increased cost can be offset by transitioning F/A-18D squadrons to the much cheaper F/A-18F. The Marine Corps can buy three F/A-18Fs for the cost of a single F-35B.

The Marine Corps should also pay close attention to the other services' testing of small turbo-prop powered light attack aircraft. Already popular in several South American nations for fighting insurgencies, the "AT-X" competition is weighing several low-cost off-the-shelf designs that could be in operational service very rapidly and with great utility to current counter-insurgency operations.[48] For low intensity conflicts of the future, these aircraft may become the close air support asset of choice. With the ability to operate out of small unprepared fields, these new light attack aircraft would provide a very low-tech and low-cost alternative to (and complement of) the F-35B. Though

envisioned as shore-based assets only, turbo-prop light attack aircraft have a drastically smaller logistical support requirement and cost much less per hour to operate than fuel-thirsty jet aircraft. Though counter to the cost saving principles of the homogenized force, a small cadre of light attack aircraft would provide the Corps a more versatile ground attack capability.

Argument for Procurement of the F/A-18F

The two-seat F/A-18F Super Hornet is nearing the end of its production run for the U.S. Navy. These aircraft represent a generational leap in technology over the F/A-18Ds currently employed by the Corps. The capability these new aircraft bring to the fight will allow Marine aviation to be more flexible and better fulfill its primary mission of supporting the Marine on the ground. As an alternative to the all STOVL force, the F-35C would provide the Corps with a CTOL aircraft for land-based (and potentially carrier-based) operations, but with an IOC date four years behind the F-35B, the USMC cannot afford to wait for the F-35C. The existing early-model F/A-18s are wearing-out too quickly to wait for a CTOL F-35.

The F/A-18F will revolutionize the way Marines provide close air support. Using the AESA radar, an advanced targeting pod, the Joint Helmet Mounted Cueing System (JHMCS), and an expanded communications suite, the F/A-18F has the capability to be the most impressive FAC(A) platform in the world. No matter how "sensor-fused", single seat aircraft are not optimum FAC(A) platforms.

Since the retirement of the A-4 and A-6, the Marine Corps has not possessed a tactical tanker. Marine Air Group (MAG) assets currently rely on the slower KC-130 for aerial refueling. An F/A-18F equipped with an aerial refueling store (ARS) is capable of

delivering over 20,000 pounds of fuel to other jet aircraft at tactical airspeeds and altitudes. Having an organic tactical tanker would be a force multiplier for the MAG commander and would provide an internal capability to increase the range of the F-35B in a high-threat scenario.

The Navy operates the F/A-18F exclusively within its carrier air wings. Continuing to employ an aircraft capable of operating in a CVW will provide the Marine Corps with basing flexibility and a stake in the future of Naval Aviation. Responsiveness and flexibility have been the hallmarks of Marine Corps aviation. The ability to integrate with USN assets aboard an aircraft carrier or at a maintenance facility ashore is a force multiplier for the Naval Service. Flying a common tac-air platform ensures simple interoperability should the need arise.

Keeping a two-seat tac-air platform in the Marine Corps also retains a high-value asset that once lost will be expensive and time-consuming to replace: the Weapon Systems Officer (WSO). Having a WSO operating the advanced crew station in the back seat of the F/A-18F with a JHMCS provides a capability in the CAS role that is unequaled in any current single seat platform. As the MAG makes its way towards an all STOVL force, the Marine Corps is phasing-out WSOs flying in the F/A-18D and EA-6B along with their aircraft. Marine WSOs serving in the FAC(A)/TAC(A) capacity complete the total integration of Marine Corps combat power like no other service can.

It is debatable whether the F-35 is even a fifth generation fighter aircraft. While certainly a generation ahead of the F/A-18F in terms of incorporated low observable design and radar absorbent coatings, the F-35 lacks the speed and maneuverability to be considered a true fifth generation aircraft. The only operational fifth generation aircraft,

the F-22 Raptor, can cruise at supersonic speeds without the use of afterburner and uses vectored thrust for superior maneuverability in slower aerial combat maneuvering. If future enemies develop technology to negate the "stealth" characteristics of the F-35, the Marine Corps will have a small force of aerodynamically inferior aircraft. From the prospective of endurance, range, and aerodynamic performance, the F/A-18F and F-35B are very similar. Other than STOVL capability, the F-35's advantages are technological and dependent on the continued dominance of the electronic spectrum by the United States and her allies.

Finally, procuring the F/A-18F at the end of its production run allows the Marine Corps to get the most refined version of the aircraft with the least amount of risk at one-third the price of the F-35B. This is how the Corps has historically procured aircraft, and with good reason. As a smaller service with a smaller budget, it is necessary to leverage cost advantages when so blatantly presented with the option. Looking beyond per unit cost to the total ownership cost of the aircraft over its projected service life, the latest study by Naval Air Systems Command suggests that the F-35B/C will cost up to 40% more to operate than the aircraft they replace.[49] This means that not only will it cost more to purchase an entire fleet of F-35s, they will be a growing burden on the operational budget of the Marine Corps.

Conclusions

Marine Corps Aviation is going through some exciting and monumental changes in force structure. The service needs a new STOVL aircraft to enable Operational Maneuver from the Sea as a viable doctrine and support Marines on the ground no matter where they land. The F-35B is the only aircraft poised to fill the mission in time to

replace the aging Harrier fleet, but alternatives still exist to wholesale adoption. Inexorably tying the future of Marine Corps aviation to a publicly flailing program, however, is not prudent. The highly politicized nature of an acquisition program as big as the F-35 is inescapable. There are international political consequences that balance the seemingly mandatory success of an ambitious and complicated program. In a fiscal environment where the phrase "too big to fail" has become a metaphor for a program requiring significant input from the American taxpayer to prevent it from collapsing under its own weight, the F-35 program indeed seems too big to fail.

When Congress requires the Marine Corps to make budget compromises, there is an easy and logical way to do it: reduce the number of F-35Bs procured over the next five years and supplement the MAG with the F/A-18F and turbo-prop light attack aircraft. An all STOVL force is tactically detrimental to the mission of the Marine Corps. The current practice of paying for unproven aircraft carte blanche endangers the future of Western combat aviation. The Department of Defense and the Marine Corps can send a strong message to the defense industry by procuring combat proven aircraft already in production and publicly exploring alternatives to the all STOVL force.

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[1] U.S. Marine Corps, Office of the Deputy Commandant for Aviation, *FY 2010 Marine Aviation Plan* (Arlington, VA: HQ USMC, November 17, 2009), 3. (herefore referenced as "FY2010 MAP")

[2] FY2010 MAP, 17.

[3] See also Figure 1.

[4] Bruce Myles, *Jump Jet: The Revolutionary V/STOL Fighter* (London: Brassey's Defence Publishers Ltd., 1986), 169.

[5] AV-8B, EA-6B, F/A-18A+/C, and F/A-18D "All Weather" squadrons will be replaced by the F-35B.

[6] Ben D. Hancock, "The STOVL Joint Strike Fighter in Support of the 21st Century Marine Corps" (Marine Corps University CSC, Quantico, VA, 1997),4.

[7] Jeremiah J. Gertler, *F-35 Joint Strike Fighter (JSF) Program: Background and Issues for Congress* (CRS Report for Congress RL30563, Washington: Congressional Research Service, December 22, 2009), 66.

[8] FY2010 MAP, 3.

[9] Jay A. Stout, *Hammer from Above: Marine Air Combat over Iraq* (New York: Presidio Press, 2005), 79.

[10] Gertler, 123.

[11] For more a more detailed comparison of the three variants, see Table 1.

[12] Mason, 58.

[13] Mason, 83.

[14] Mason, 83.

[15] Lon O. Nordeen, *Harrier II: Validating V/STOL* (Annapolis, MD: Naval Institute Press, 2006), 75.

[16] Nordeen, 137.

[17] Nordeen, 137.

[18] Sean Rayment, "Harrier destroyed by Afghan rocket" (*telegraph.co.uk.* October 16, 2005). http://www.telegraph.co.uk/news/uknews/1500702/Harrier-destroyed-by-Afghan-rocket.html (accessed January 19, 2010).

[19] Krulak, 83.

[20] FY2010 MAP, 3. Quote attributed to Lt.Gen.Trautman, Deputy Commandant for Aviation, USMC.

[21] Charles C. Krulak, "Operational Maneuver from the Sea"(*Joint Forces Quarterly*, Spring 1999), 84.

[22] John E. Rhodes, "Statement of Lieutenant General John E. Rhodes, Commanding General Marine Corps Combat Development, United States Marine Corps, before the Senate Armed Services Committee, Seapower Subcommittee" (Testimony concerning 21st Century Seapower, Washigton, DC, March 3, 1999).

[23] Myles, 113.

[24] Francis K. Mason, *Harrier* (Annapolis, MD: Naval Institute Press, 1983), 57.

[25] Myles, 173.

[26] Myles, 164.

[27] Gertler, 10.

[28] From http://en.wikipedia.org/wiki/A_Cooperative_Strategy_for_21st_Century_Seapower: "A Cooperative Strategy for 21st Century Seapower" is the United States' newest maritime strategy. It was presented by the U.S. Chief of Naval Operations and the Commandants of the U.S. Marine Corps and U.S. Coast Guard at the International Seapower Symposium at the U.S. Naval

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[29] Wayne P. Hughes, Jr., *The New Navy Fighting Machine: A Study of the Connections Between Contemporary Policy, Strategy, Sea Power, Naval Operations, and the Composition of the United States Fleet* (Study sponsored by the Secretary of Defense's Office of Net Assessment, Monterey, CA: Naval Postgraduate School, August 2009), 23.

[30] Hughes, Jr., 27.

[31] Hughes, Jr., 26.

[32] Stout, 5.

[33] Reference MARADMIN 0003/10, DTG: 041842ZJAN10. Available at: http://www.marines.mil/news/messages/Pages/maradmins.aspx.

[34] Grace V. Jean, "Marines Question the Utility of Their New Amphibious Warship" (*www.nationaldefensemagazine.org,* September 2008), http://www.nationaldefensemagazine.org/archive/2008/September/Pages/MarinesQuestiontheUtilityof.aspx (accessed January 20, 2010).

[35] Stout, 6.

[36] Nordeen, 122.

[37] 2010 MAP, 81.

[38] 2010 MAP, 80.

[39] Nordeen, 33.

[40] Lance M. Bacon, "Bataan ARG home after delivering Ospreys" (*Navy Times,* December 8, 2009). http://www.navytimes.com/news/2009/12/navy_bataan_home_120809w/ (accessed January 13, 2010)

[41] Christopher P. Cavas, "Navy argues against Marine variant of JSF" (*marinecorpstimes.com,* May 1, 2007). http://www.marinecorpstimes.com/news/2007/04/defense_stovl_jsf_070430m/ (accessed January 20, 2010).

[42] U.S. Government Accountability Office, *Joint Strike Fighter: Strong Risk Management Essential as Program Enters Most Challenging Phase* (Report to Congressional Committees, Washington, DC: U.S. Government Accountability Office, May 2009), 15. (herefore referenced as "GAO: JSF risk management")

[43] Robert M. Gates, "Media Availability with Secretary of Defense Robert Gates at Lockheed Martin Factory, Fort Worth, Texas" (*Deffense.gov*, August 31, 2009). http://www.defense.gov/Transcripts/Transcript.aspx?TranscriptID=4469 (accessed January 18, 2010).

[44] GAO: JSF risk management, 2.

[45] Gertler, 8.
[46] GAO: JSF risk management, 2.

[47] Gertler, 66.

[48] Marcus Weisgerber, "The Light Attack Aircraft" (*AIR FORCE Magazine*, January 2010), 56.
[49] David E. Burgess, *Joint Programs TOC Affordbility* (Patuxent River, MD: Naval Air Systems Command, January 4, 2010).

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Figure 1: Marine Aviation Transition

from Office of the Deputy Commandant for Aviation. *FY 2010 Marine Aviation Plan*

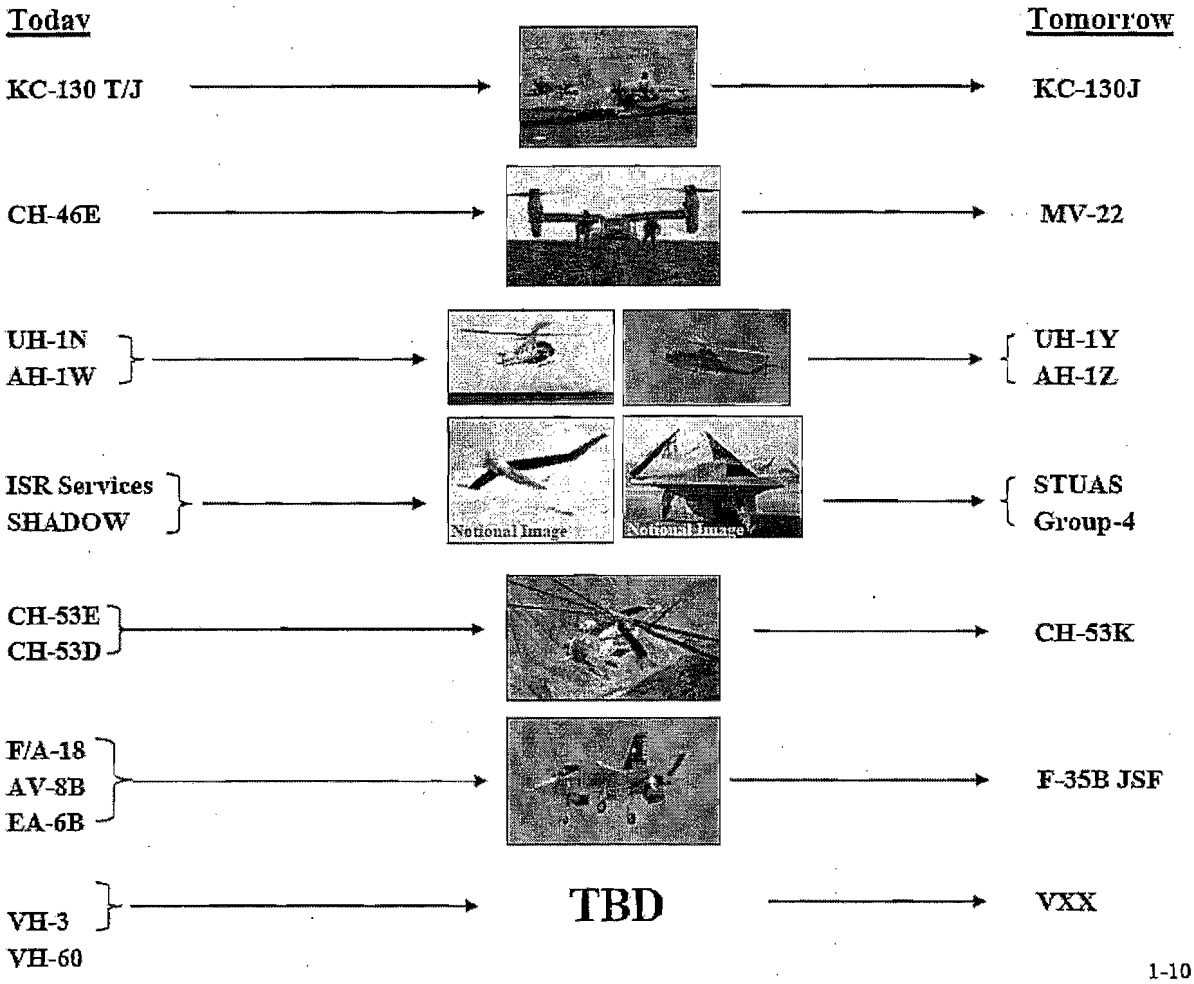

Table 1: F-35 Key Performance Parameters (KPPs)

from *F-35 Joint Strike Fighter (JSF) Program: Background and Issues for Congress* , p.123

Source of KPP	KPP	F-35A Air Force CTOL version	F-35B Marine Corps STOVL version	F-35C Navy carrier-suitable version
Joint	Radio frequency signature	Very low observable	Very low observable	Very low observable
	Combat radius	590 nm Air Force mission profile	450 nm Marine Corps mission profile	600 nm Navy mission profile
	Sortie generation	3 surge / 2 sustained	4 surge / 3 sustained	3 surge / 2 sustained
	Logistics footprint	< 8 C-17 equivalent loads (24 PAA)	< 8 C-17 equivalent loads (20 PAA)	< 46,000 cubic feet, 243 short tons
	Mission reliability	93%	95%	95%
	Interoperability	Meet 100% of critical, top-level information exchange requirements; secure voice and data		
Marine Corps	STOVL mission performance – short-takeoff distance	n/a	550 feet	n/a
	STOVL mission performance – vertical lift bring-back	n/a	2 x 1K JDAM, 2 x AIM-120, with reserve fuel	n/a
Navy	Maximum approach speed	n/a	n/a	145 knots

Source: F-35 program office, October 11, 2007.

Notes: PAA is primary authorized aircraft (per squadron); vertical lift bring back is the amount of weapons with which plane can safely land.